Using tracker for jet energy correction

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- **Calorimeter consists of two compartments and both has different response to electrons and hadrons**

- **Jets have both hadronic (charged and neutrals) and e/γ components.**

Short description of procedure:

- **Energy of charged hadrons of jet is taken from Tracker**

- **Response of charged hadrons is subracted from ECAL and HCAL**

Response (e/γ+neutral)_ECAL=Response_ECAL− Response(charged)_ECAL

Response (neutral)_HCAL=Response_HCAL− Response(charged)_HCAL

Jet energy=E_TRACKER+ Response (e/γ+neutral)_ECAL+ Response (neutral)_HCAL

Response can be calculated in different ways:
library of responses, e/π technique (used below)

Simplifications:

- **QCD dijet events with Pthat 100−110 GeV are generated with PYTHIA 6.152 using parameters from jet production 2000.**

  Jets from interval 90−105 GeV were taken.
  Only jet particles in cone 0.5 on generator level are propagated through cmsim 121.

- **The entry point of charged particles to ECAL was taken from generation on CMSIM level.**

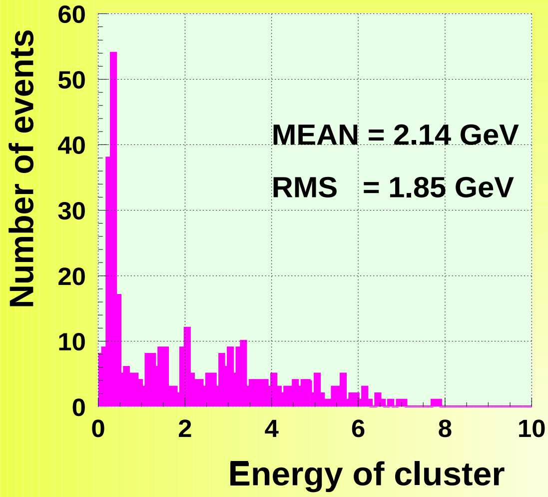
  No reconstruction algorithms in tracker were used

- P**arameters of algorithm:**
  (e/h)_(ECAL), (e/h)_HCAL, E_ECAL/E_HCAL for charged particles− used in algorithm were taken from test−beam data where HCAL was calibrated to electrons.

  In CMSIM121 HCAL is calibrated to 50 GeV pions
  E_ECAL/E_HCAL depends on particle energy

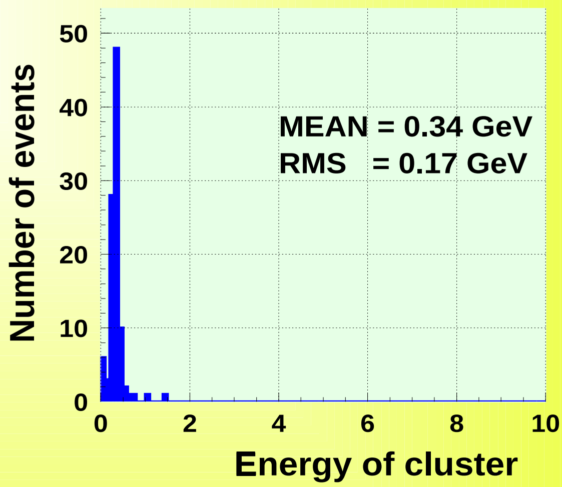
Single pion

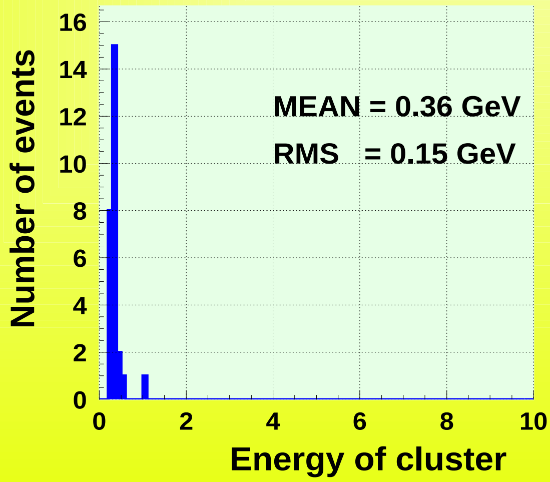
Energy deposition in 3x3 crystalls around entry point of particle in ECAL for 10 GeV pion.



Pion interacted in ECAL
All hadronic interactions including coherent ones

No hadronic interactions+ coherent interactions



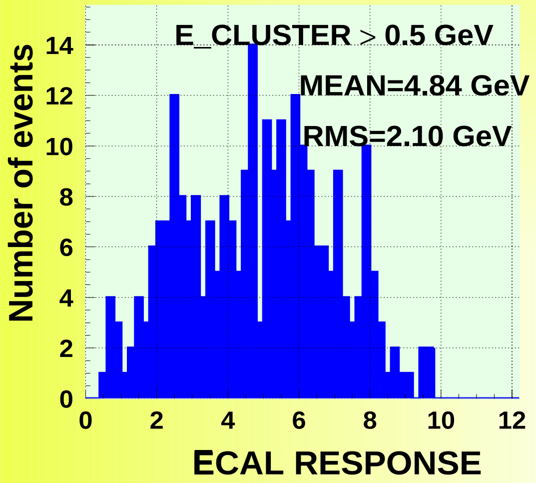


No hadronic interaction in ECAL

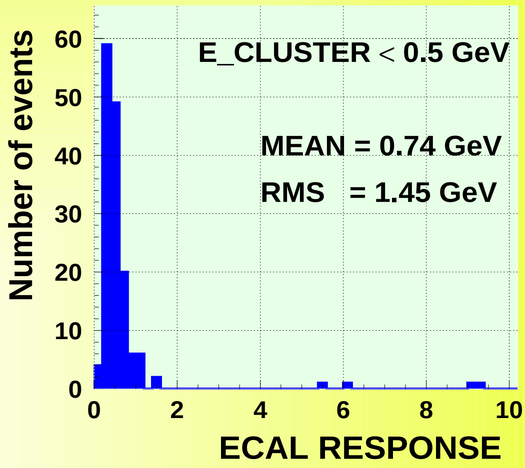
One need to define if charged particle is interacted in ECAL or not.

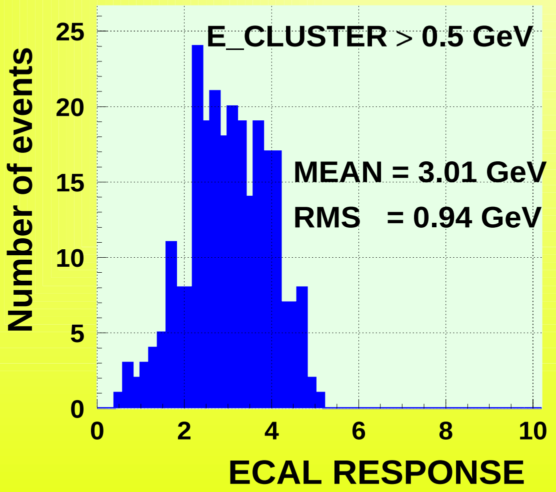
Energy deposition in 3x3 crystalls were taken around entry point of each charged particle reached ECAL.

E3x3>0.5 GeV/c **E3x3<0.5 GeV/c**

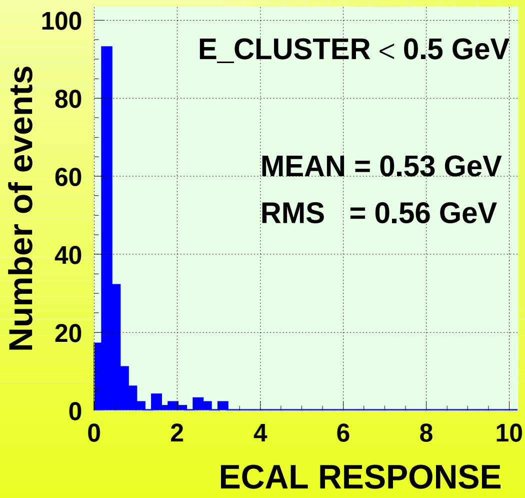


10 GeV pions

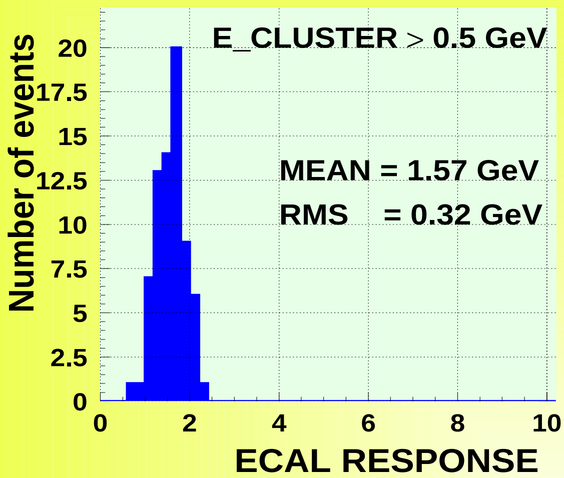


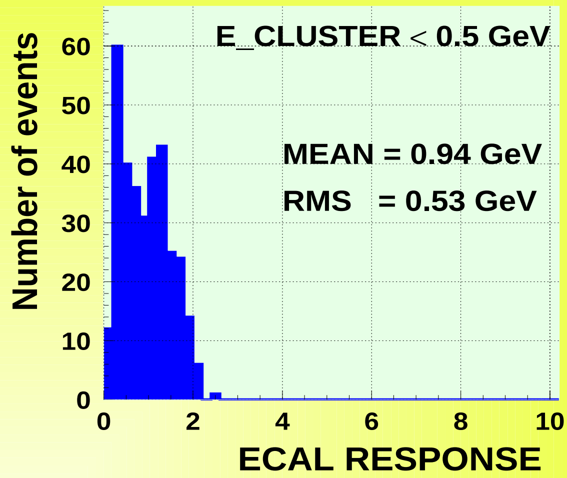


5 GeV pions



E3x3>0.5 GeV **2 GeV pions** **E3x3<0.5 GeV**





Jets

Comparison of number of particles (%) of different energies with E3x3< or > 0.5 GeV/c for single particles and particles in 100 GeV jet.

For case of jets energy intervals 2−5 GeV, 5−10 GeV and >10 GeV were taken.

Energy(GeV	E3x3<0.5 GeV/		E3x3>0.5 GeV/c	
	Single	Jet	Single	Jet
2	82	45	18	55
5	40	28	60	72
10	36	17	64	83

In a case of jets the probability to have E3x3<0.5 GeV two times less then for single particles.

For each interacted charged particle Dan Green's procedure to find response of this particle in ECAL and HCAL is used to calculate mean response in calorimeters.

For each charged the ratio of responses to electrons and pions is calculated:

$$e/\pi(ECAL)=e/h(ECAL)/(1+(e/h(ECAL)-1)*F0\_ECAL$$

$$e/\pi(HCAL)=e/h(HCAL)/(1+(e/h(HCAL)-1)*F0\_HCAL$$

$$F0\_ECAL=0.11*\log(E\_ECAL)$$

$$F0\_HCAL=0.11*\log(E\_HCAL)$$

F0_ECAL,HCAL−electromagnetic fraction of hadronic shower.
E_ECAL, E_HCAL − energy deposited in ECAL,HCAL
e/h is obtained by fitting test−beam data.

For each non−interacted charged particle E3x3 is used to calculate mean response in calorimeters.

Two points:
How one can distinguish whether particle is interacted?
We use matrix from E3x3 crystalls as on previous slides.
How to define E_ECAL, E_HCAL? Next slide.

How deposited energy E_ECAL, E_HCAL are evaluated:

Particle interacted in ECAL

E_ECAL=0.4*Etracker (test beam, talk of J.Freeman)

E_HCAL=0.6*Etracker

Particle does not interact in ECAL

E_ECAL=E_MIP (energy from EM cluster)

E_HCAL=Etracker−E_MIP

Response from charged particles is calculated.

Particle interacted in ECAL

R_ECAL=E_ECAL/(e/π)(ECAL)

R_HCAL=E_HCAL/(e/π)(HCAL)

Particle does not interact in ECAL

R_ECAL=E_MIP

R_HCAL=E_HCAL/(e/π)(HCAL)

Calculation of jet energy.

✔ Energy (R(ECAL), R(HCAL) is calculated in cone around jet axis using standard procedure and with default coeffients.

✔ Summarized response from charged particles with entry point inside a cone is subtracted from R(ECAL), R(HCAL).

Two variants:

a) only particles with entry point in cone 0.5 around jet axis

b) item a)+particles outside cone on the surface of ECAL are taken with Etracker.

$E_{EM+neutral}$(ECAL)=R(ECAL)−sum(R_ECAL_i)

$E_{neutral}$(HCAL)=R(HCAL)−sum(R_HCAL_i)

Ejet=$E_{EM+neutral}$(ECAL)+$E_{neutral}$(HCAL)+Etracker

Etracker=sum(Etracker_i)

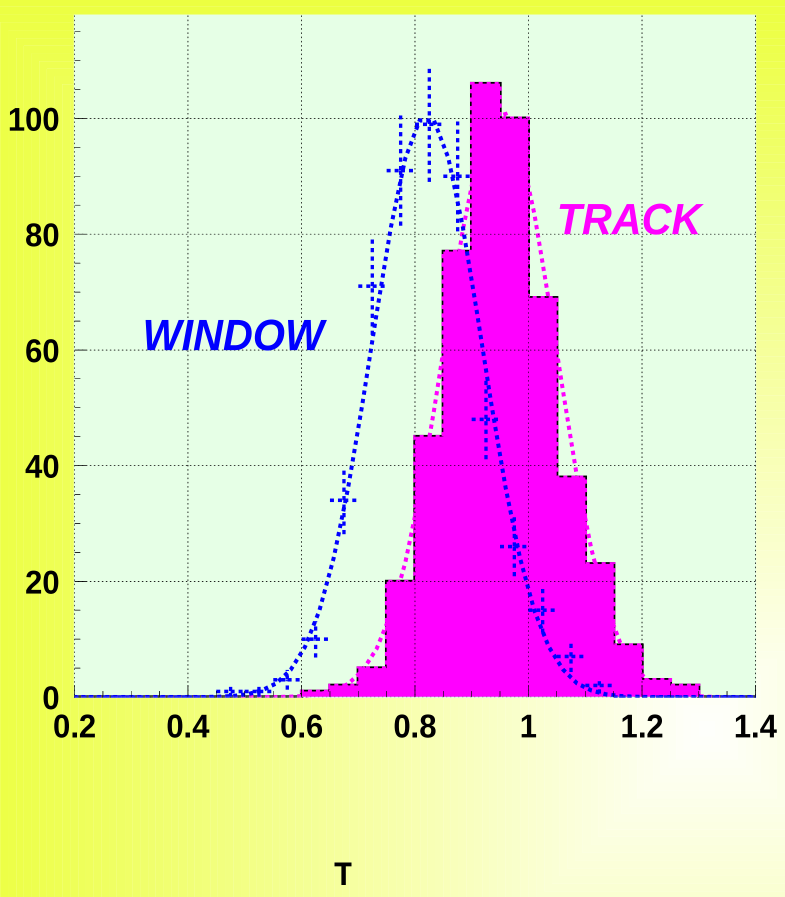
From test−beam results:

e/h(ECAL)=1.6

e/h(HCAL)=1.39

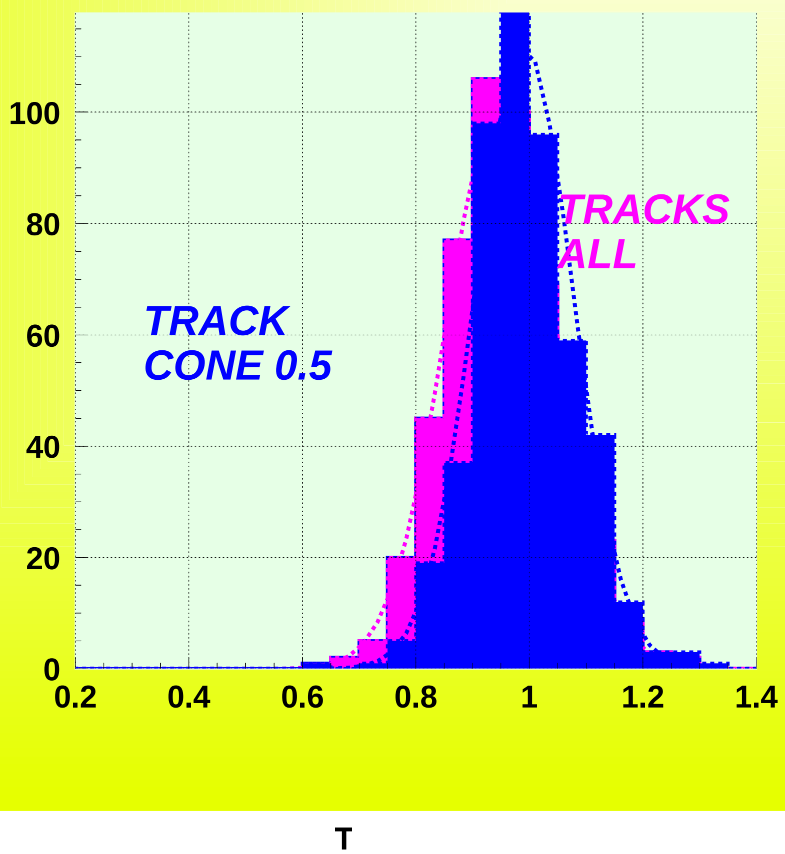
E_ECAL=0.4 Etracker for each particle

For 100 GeV jet (500 events):



Window algorithm
Mean=0.821+−0.005
sigma=0.097+−0.004
Resolution=11.82%
+−0.5%

Tracks in cone
Mean=0.95+−0.004
sigma=0.097+−0.004
Resolution=10.2%
+−0.5%



Tracks in cone +
tracks out of cone
Mean=0.991+−0.004
sigma=0.087+−0.003
Resolution=8.8%
+−0.5%

Why $D(E_{jet}^{rec}/E_{jet}^{gen})/\langle E_{jet}^{rec}/E_{jet}^{gen}\rangle$ should be better:

Only calorimeter information:

$$E_{jet}^{calo}=\sum Response\ (e/\gamma)$$
$$+\sum Response(neutral)+\sum Response(charged)$$

$$D(E_{jet}^{calo})=\sum D(Response\ (e/\gamma))$$
$$+\sum D(Response(neutral))+\sum D(Response(charged))$$

Include Tracker information:

$$E_{jet}^{tracker}=\sum Response\ (e/\gamma)$$
$$+\sum Response(neutral)+\sum Response(charged)$$
$$-\sum Response(charged)\_teor$$
$$+\sum Etracker=$$
$$=E_{jet}^{calo}+\sum Etracker-\ \ \sum Response(charged)\_teor$$

$$D(E_{jet}^{tracker})=D(E_{jet}^{calo})+\sum D\left(Etracker\right)$$
$$-\sum D(Response(charged)\_teor)=$$
$$=D(E_{jet}^{calo})$$

Dispersion is kept unchanged but mean energy become closer to it's value on generator level.

Summary

We considered two different cases of using tracker information:

a) energy of tracks that have impacts within cone 0.5 on ECAL surface is taken from tracker.

b) we add tracks that are outside cone 0.5 to a).

In case a) mean value of the $E_{Tjet}^{rec}/E_{Tjet}^{gen}$ becomes 0.95 istead of 0.82 for standart window algorithm and resolution becomes 10.2% (15% improvement) instead of 11.8%

In case b) mean value of the $E_{Tjet}^{rec}/E_{Tjet}^{gen}$ becomes 0.99 istead of 0.82 for standart window algorithm and resolution becomes 8.8% (25% improvement)

What should be changed in nearest future:

For energy deposition sharing between ECAL and HCAL one should take a dependence on Etracker instead of fixed value 0.4:0.6

e/h for ECAL and HCAL was calculated for HCAL calibrated on electrons and in CMSIM it is calibrated to the 50 GeV pions.

Subtraction of particles response from jet response in cone should depend on the distance between cone boundary and particle entry point.

Additional improvement can be expect if one combines this metodology with special treatment of isolated particles